

Implementation of FFT in Industrial Induction Motor Monitoring via Mobile Phone

Afzeri*, Deni Kurnia, Muhammad Nur Hakim, and Indriani Siti Nurmala

Program Studi Mekatronika, Politeknik Enjening, Indoroma, Indonesia

*email: afzeri@pei.ac.id

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ABSTRACT– Competition in the industrial world requires companies to always improve efficiency in the production process. The use of communication technology in the monitoring process is one way to reduce effort in monitoring equipment. This study aims to create a mobile phone-based online control and monitoring system for induction motor parameters in the industry without interfering with the motor's electrical network. The monitoring system is carried out by monitoring the vibration and temperature of the induction motor using the GY-521 MPU-6050 sensor connected to the NodeMCU ESP8266 as the control device. For the data computation process to obtain rotational parameters, the Fast Fourier Transform (FFT) function is applied to transform the vibration data from the accelerometer into the frequency domain. In the data collection process, 250 data samples were captured in 1 second which were formed from vibrations of the X, Y and Z direction motors. Manual ON/OFF control of the electric motor and automatic OFF was carried out when a spike in the vibration frequency of the motor was detected. The test was carried out with four variations of rotation conditions. The test results show that the rpm speed of the motor can be obtained based on the difference in the frequency of motor vibration. This data is then sent online to observer technician via the Telegram application installed on the mobile phone device. The system performance as a whole shows quite good performance both in terms of equipment placement, data processing and delivery.

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Introduction

Research on online industrial motor control and monitoring systems has been carried out by many previous researchers with various methodologies. Among these studies is a three-phase induction motor control monitoring system with PLC-based variables[1], there is also a web-based[2] and the Internet of Thing (IoT)[3]. Furthermore, other studies have also discussed network monitoring systems based on ICMP, SCADA[4], NodeMCU[5] and notification systems using the Telegram platform[6][7]–[9].

Several studies have carried out condition monitoring through the FFT method such as pressure measurement for centrifugal pumps where Fourier converts the signal to make inferences about pump behavior. [10] and Monitoring and Control of Induction Motor Parameters in Real-time by Monitoring the current values of three-phase Induction motors such as motor rotation, power consumption, and operating frequency [11].

In connection with this topic, then referring to previous research on control and monitoring system engineering [12], [13], this study intends to fill the gap from previous research by applying the FFT algorithm [14], [15] to the data computation process that combines mobile phone application as online media monitoring and NodeMCU[16] as the control

device. FFT is used as a sensor system to measure motor rotation remotely.

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The fast Fourier transform (FFT) is a method that calculates the discrete Fourier transform (DFT) of a sequence of data. Fourier analysis converts a signal from its origin domain (often time or space) into a frequency domain representation. DFT is obtained by decomposing a sequence of values into different frequency components [17]. This operation is useful in many fields of application. Although calculating directly from the definition is often time consuming, the high capabilities of today's microcontrollers allow transformation data to be calculated quickly.

An FFT can quickly calculate transformations by factoring the DFT matrix into the product of sparse factors. Studies on the use of the Fast Fourier Transform (FFT) method to calculate speed of motor rotation in revolutions per

minute (rpm) have been widely implemented in various studies. The pulse signal value from the rotary encoder or vibration sensor is captured and converted into the frequency domain [18][19].

In this study, it has not yet discussed how to implement it in the industry with installations that do not affect production performance, especially for systems that are already in operation. The industry which is the object of this research is the textile industry which uses various sizes of induction motors. The purpose of using the FFT as a vibration data processor is to avoid installing a sensor system that interferes with the function of the motor where it is enough to place it on the outside of the body. Measurement of vibration characteristics is used to detect as an indication of abnormalities in motor operation.

Currently there are more than 5,000 motor units in this industry with powers ranging from 0.25 kW to 250 kW which are still not connected for the monitoring process. Based on maintenance data, these induction motors often experience damage to their bearings and windings[20]. Therefore it is necessary to do prevention by monitoring rotation, checking vibration and temperature of the induction motor which is monitored in real time from a distance, so that technicians can find out signs of damage early even though they are not on site.

Different control technologies have been used for system monitoring and control, while communication between system and user is generally realized online through wireless communication techniques such as Rf, Bluetooth and GPRS in remote monitoring [21][22].

For monitoring efficiency and effectiveness, industries are starting to implement installed equipment to be monitored online. High mobility and flexibility in supervision have become targets for the industry in ensuring the quality and efficiency of the production process.

Material and Methods

Disruption of the production process for installation, both in the installation and operation of the sensor system, is a reference in selecting tools and research methods. Practicality in installation and not disrupting production operations is the focus of this research in order to facilitate implementation that is acceptable to the industry.

Studies have been carried out using the Fast Fourier Transform (FFT) method to convert frequency into speed in revolutions per minute (rpm) of an induction motor. This method aims to detect the rotation produced by an induction motor without placing a rotation sensor on the motor. Placement of the rotation sensor can cause interference with motor operation.

Motor Side Equipment

The research was carried out through prototyping as an experimental means such as the tool shown in Figure 2a. In the early stages, an investigation was carried out on motor monitoring problems in the textile industry. The next stage is designing a prototype using a single phase induction motor that is equipped with sensors and monitoring installations. Monitoring is carried out by observing the working

conditions of the induction motor by sending data to the telegram application installed on the mobile phone device. The vibration sensor and temperature sensor use the GY-521 MPU-6050 accelerometer module, as illustrated in Figure 1 while the data processing controller uses the NodeMCU ESP8266 (Figure 2).

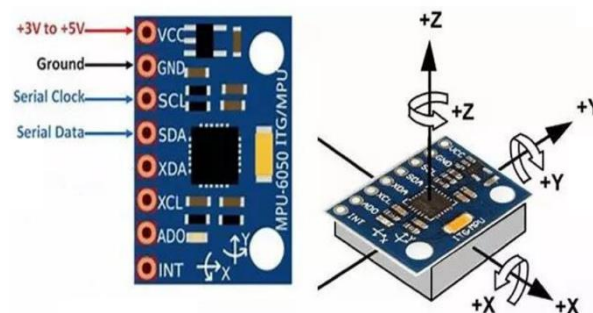


Figure 1. GY-521 MPU-6050 3 Axis Accelerometer Gyroscope Sensor

The GY-521 MPU-6050 is the most common accelerometer and gyroscope sensor module found in the market in the form of one solid module. This module detects vibrations in the three-dimensional x, y, and z directions in translational and rotational ways which respond simultaneously.

This module is equipped with an ADC or Analog to Digital Converter feature with a 16-bit resolution so that the resulting data will be more accurate and better. By using this sensor, changes or movements of objects in space can be observed for changes in values in the x, y, and z angles.

The GY-521 MPU-6050 which is equipped with an Interrupt (INT) pin as an interrupt program has an IIC interface to connect with microcontroller devices that have the same features. The NodeMCU ESP8266 which is used as a controller and data processor is an open source IoT (Internet of Things) platform that can be programmed using the Arduino IDE sketch. This ESP8266 module has a GPIO and is equipped with PWM (Pulse Width Modulation), IIC, 1-Wire and ADC (Analog to Digital Converter) features, all on one board. Through the IIC interface, the vibration sensor module is connected to the NodeMCU to capture vibration data efficiently.

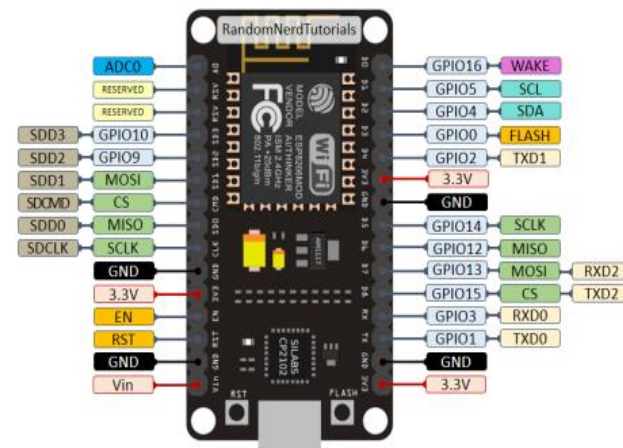


Figure 2. NodeMCU ESP8266

Furthermore, in carrying out the hardware design, the sensor is placed on the motor body (Figure 3a) using a specially made holder (Figure 3b). The holder is designed so that its placement on the motor is carried out without interruption. Place sensors and electrical wiring in such a way that they are not connected to existing motor electrical installations. The goal is that the addition of sensors does not affect the installation conditions of the motor, so it does not affect the quality of the motor performance which affects the quality of production. Besides that, by simply placing the sensor on the body without a wiring connection, it makes installation easier without having to stop the motor. This method is needed with the aim that the installation of equipment does not interfere with the production process.

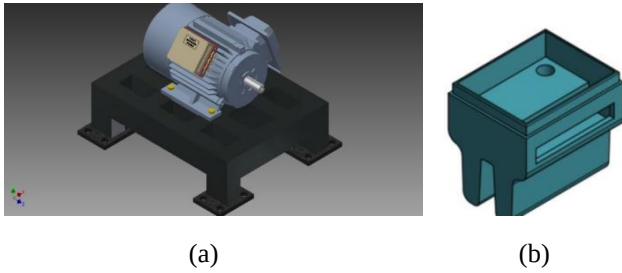


Figure 3(a). Induction Motor with *NodeMCU ESP8266* and Sensor *GY-521 MPU-6050*. **(b).** Holder Sensor

Figure 4 shows the prototype device with motor, sensor used in the research. The motor is equipped with a rotation sensor as a comparison between the FFT results and the actual rotation. The frame is made stiff enough with short legs to reduce the influence of the resonant vibrations generated by the table stand.

At the programming stage, an algorithm is designed for data processing and battery condition detection. Computation of vibration data obtained from sensors is processed in the *NodeMCU ESP8266* program using the FFT (Fast Fourier Transform) method which provides two sides of the spectrum in complex forms (real and imaginary). Then it is scaled and converted into polar form to get the magnitude. The amplitude of the FFT is related to the number of points in the time domain. To get the amplitude versus frequency of the FFT, the following equation is used:

$$\text{Amplitudo Spektrum Peak} = \frac{\text{Magintude(FFT)}}{N} = \sqrt{\frac{(|\text{real}|FFT(A)|)^2 + (|\text{imag}|FFT(A)|)^2}{N}} \quad (1)$$

$$\text{Phase in radian} = \text{Phase}(FFT(A)) = \arctan\left(\frac{|\text{imag}|FFT(A)|}{|\text{real}|FFT(A)|}\right) \quad (2)$$

The two-sided spectrum shows half the peak amplitude at positive and negative frequencies. To convert it into a single-sided spectrum, it is multiplied by the frequency. The single-sided unit gives the peak value of the sinusoidal component. To show the amplitude of the spectrum in volts rms, divide the non-DC component by root 2 after converting the spectrum to single-side by the following equation:

$$\text{Amplitude in Volt rms} = \frac{\text{Magintude(FFT(A))}}{N} = \text{for } i = 1, \text{ until } \frac{N}{2} - 1 = \frac{\text{Magintude(FFT(A))}}{N}, \text{ for } i = 0 \quad (3)$$

Where i is the frequency index.

$$\text{Phase in deg} = \frac{180}{\pi} * \text{Phase}(FFT(A)) \quad (4)$$

The power spectrum of the two-side can be calculated:

$$\text{Powerspectrum } S(f) = \frac{FFT(A) \cdot FFT^*(A)}{N} \quad (5)$$

$FFT^*(A)$ is a complex conjugation of $FFT(A)$.

Data collection is carried out on a client-side system with sensors controlled by *NodeMCU ESP8266*. The steps for data collection are carried out as follows:

1. Determine the accumulation of 250 sampling data in 1 second which is detected from the vibration amplitude of industrial motors using the MEMS MPU6050 vibration sensor.
2. Detects battery capacity to form an auto-charging system.
3. Controlling the electric motor ON or OFF manually and/or automatically OFF when abnormal motor rotation or vibration is detected.
4. Determine the average of 250 samples of vibration waves, temperature, electrical energy, and RPM, then display them to the Telegram application as a control and monitoring system.

Communication System Device

The Telegram application is used as a communication device for the user side by sending data in the form of FFT conversion results, temperature and other vibration data. Telegram is a messaging app with a focus on speed and security that works really fast and simple. Telegram can be used on Smartphone devices at the same time where the messages can sync seamlessly across a number of phones.

Basically Telegram, can send messages, photos, videos and files of any type like doc, zip, mp3, etc sent by individuals or systems. Sending messages from ESP8266 equipment is done by installing the Telegram Bot library then initializing it with the Bot Token requested via the Telegram server with the Telegram Bot bot syntax (BotToken, net_ssl), where net_ssl is a variable for wifi. Next, initialize the Bot with the bot.begin() command. Receiving messages from outside is done with the command message m = bot.getUpdates(), while sending data to Telegram users is used via the command bot.sendMessage(chat_id, text), where chat id is the intended Telegram id and text is the message to be sent. In this study, the text variable is filled with the detected sensor parameters, namely: temperature and frequency of the results of the FFT transformation.

Results and Discussion

The final stage of this research is testing the tool. Testing is carried out by taking data from each experiment to determine the performance and deficiencies of the system and to obtain research data. RPM is measured using a tachometer as a comparison which is used as the basis for getting the actual rotation.

The graph in Figure 4 shows the results of vibration readings from the accelerometer which have been transformed to the frequency domain using the FFT function. The flat axis is the frequency and the vertical axis is the transformed amplitude. The following is a graphic explanation in Figure 5:

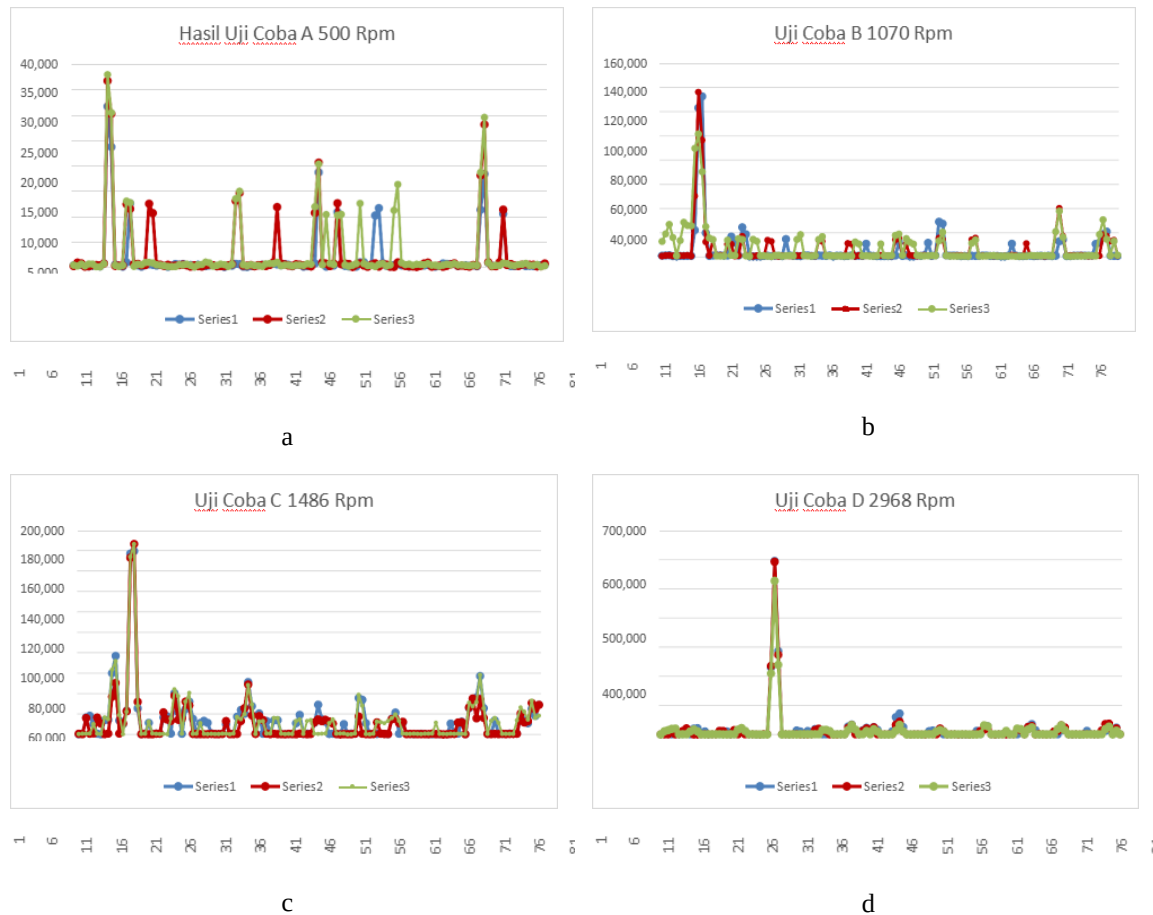


Figure 4. Vibration Test Graph with Four Different RPM Conditions

- Graph 4a is the reading of the acceleration sensor at 500 rpm. The highest amplitude is read at number 6, but other amplitudes are read at different frequencies such as another peak at number 70.
- Graph 4b is the result of 1070 rpm rotation acceleration sensor readings. This graph shows very clearly the frequency of excitation occurring on a scale of 8. .
- Graph 4c is the result of reading the acceleration sensor at 1486 rpm. This graph shows very clearly the frequency of excitation occurring on a scale of 11.
- Graph 4d is the result of reading the acceleration sensor at 2968 rpm. This graph shows the frequency of excitation occurring on a scale of 23. .

Furthermore, from the control and monitoring side via mobile phone with the Telegram application, the results obtained can be shown in Figure 5. From Figure 5 it can be explained that for the monitoring process, data is sent via the telegram application in the form of frequency and temperature. The control process for turning off the motor can be done through the application by giving the /OFF instruction needed in the event of a frequency spike which results in abnormal vibration of the motor through the Max Accel parameter.

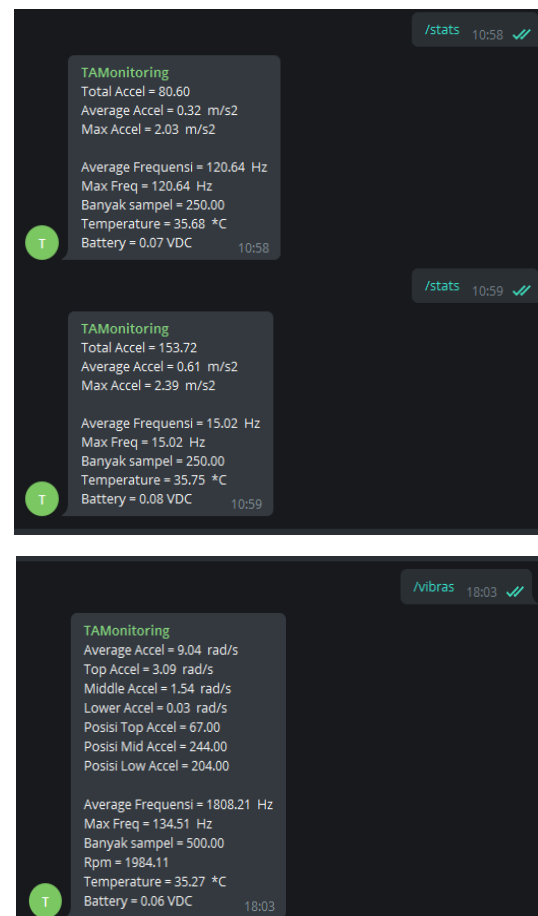


Figure 5. Data Display via The Telegram App

Conclusion

The Fast Fourier Transform (FFT) algorithm applied to the NodeMCU ESP8266 program provides quite effective performance in transforming vibration data into the frequency domain. From several test results it can be seen that the difference in motor vibration frequency can be obtained based on changes in the rpm speed of the motor where the motor experiences excitation frequency at rotation due to resonance. Then for control and monitoring systems, the telegram application installed on a mobile phone device is able to provide data information with an informative display in real time. The results of the study show that without specifically placing a rotation sensor it is able to detect motor rotation so it does not interfere with the electrical network and also sensor placement can be done without stopping the motor.

Acknowledgments

Competing Interest

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